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Microhabitat segregation among three co-existing species of grasshoppers on a rural meadow near Seoul, South Korea

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Abstract

Microhabitat segregation among grasshopper species in Asia has not been well studied. We determined the differences in the use of substrates by three common North East Asian grasshopper species co-existing on a natural meadow near Seoul, South Korea. While many *Oedaleus infernalis* individuals were found on the ground, *Acrida cinerea* and *Atractomorpha lata* were usually observed on plants. *Acrida cinerea* was mostly observed on the grass *Zoysia japonica* (Poaceae) and *Atractomorpha lata* was mostly found on plants from the family Asteraceae. This is the first study to provide quantitative information about microhabitat differences among some common grasshoppers in rural habitats of continental North East Asia. Future studies should focus on determining the mechanisms that produce such ecological segregation.

Key words

Acrida cinerea, *Atractomorpha lata*, ecology, microhabitat, *Oedaleus infernalis*

Introduction

Microhabitat selection is important for small ectothermic animals including insects (Ahnesjö and Forsman 2006, Gardiner and Hassall 2009), and for herbivores with specific diets (including those that sequester unpalatable chemicals from plants for their own protection against predators; Sword et al. 2000, Sword 2002). Different species of grasshoppers have different diets (Joern 1979, Otte 1981, Chu 2002) and they move between sunlit and shaded areas to control their body temperature (Pielou 1948, Ahnesjö and Forsman 2006). Grasshoppers also choose microhabitats that provide better camouflage (Eterovick et al. 1997). Microhabitat segregation among co-existing species of grasshoppers has been studied in North America and Europe (Isely 1937, Joern 1979, 1982, Gardiner and Hassall 2009), but rarely studied in Asia (Tan et al. 2017, T. Gardiner pers. comm.). Here, we provide basic information on microhabitat segregation among three common grasshopper species in South Korea (Park and Kim 2011) and Japan (Yoshioka et al. 2010). We chose to study the three species that were the most common at our study site: *Acrida cinerea* (Thunberg, 1815), *Atractomorpha lata* (Mochulsky, 1866), and *Oedaleus infernalis* Saussure, 1884. From classical ecological theory (Hardin 1960) and based on previous studies on grasshoppers (Isely 1937, Joern 1979, 1982, Gardiner and Hassall 2009, Tan et al. 2017), we expected that they would differ in their ecological niches.

Materials and methods

The observation site (37°24.07′N, 126°44.62′E) was comprised of a 10,000 m^2 lush grassland adjacent to Soraepogu Ecological Park, with an abundance of plants belonging to Asteraceae, especially *Artemisia princeps* and *Aster pilosus*. A hiking path crossed the meadow and each side of the trail was covered with a 1-m wide band of *Zoysia japonica*. To determine microhabitat segregation among the three species, we used a modified point-sampling technique (Joern 1982). A researcher moved very slowly through the grassland (including the 1-m wide band of *Zoysia japonica*) and noted the location of each detected individual grasshopper and the plant species (or ground) it was sitting on (or just jumped from). Each grasshopper species has distinctive morphology making the identification of species in the field relatively easy (Storoženko and Paik 2007, Kim 2013). Observations were carried out for four days from the end of August to the beginning of September 2017 and resulted in 327 grasshopper presence records. Plants were classified into four structural types which roughly aligned with plant family: **Stem-plants**, usually Asteraceae, consisted of one straight stem with leaves emanating to all sides; **Low-vegetation** plants, usually *Zoysia japonica* (Poaceae), were short and formed relatively dense cover; and **Tall-grass** included tall (50–150 cm) Poaceae with long and thin grass leaves. Other records of grasshoppers on rarely observed plant species were put into the category **Others**. Observations on the ground were classified into the **Ground** category. Plant structural type was closely correlated with plant family, so they are not independent. We performed two analyses,

one utilizing plant family as the dependent variable and the other utilizing structural type, as two alternative and correlated analyses of substrate use by grasshoppers. We used the Fisher's exact test (function *fisher.test* from the stat-package in R; Mangiafico 2015) to statistically test the null hypothesis of no differences among the three grasshopper species in their use of substrates. This test was most appropriate because our data were in frequency tables with a small number of records in some of the cells.

Results and discussion

The three grasshopper species differed significantly in their association with different plant families (Fig. 1A; Fisher's exact test $P < 0.001$). While many individuals of *Oedaleus infernalis* were found on the ground, most *Acrida cinerea* and *Atractomorpha lata* were observed on Poaceae (usually *Zoysia japonica*) and Asteraceae (usually *Artemisia princeps* or *Aster pilosus*), respectively (Table 1). The three grasshopper species also differed significantly in their association with different plant structural types (Fig. 1B; Fisher's exact test $P < 0.001$). *Acrida cinerea* was most often observed on **Low-vegetation** structure plants (mostly Poaceae), *Atractomorpha lata* was mostly found on **Stem-plants** (mostly Asteraceae), and *Oedaleus infernalis* was largely observed on the **Ground**.

Atractomorpha lata utilizes host plants belonging to various families including Asteraceae, Convolvulaceae, and Fabaceae (Tanaka 2008). In this study, many *Atractomorpha lata* individuals were observed on Asteraceae. This is consistent with previous findings that *Artemisia princeps* (Asteraceae) is one of the best host plants for growth and survival of *Parapodisma subastirs* grasshoppers (Miura and Ohsaki 2004a, b, 2006). As we did not determine the relative abundance of different plant species at the study site, we cannot directly evaluate the host plant preferences of each species. However, we can focus on microhabitat differences between the three species at the same location.

While *Atractomorpha lata* was found on Asteraceae as well as other plant families, *Acrida cinerea* was mostly observed on Poaceae (usually *Zoysia japonica*). *Acrida* spp. grasshoppers are known to prefer grass as a food resource (Haldar et al. 1995). We also hypothesize that these differences in host plant associations may be linked to specific thermal microhabitat. *Zoysia japonica* on the research site had recently been trimmed and so the grass was shorter than normal, which might have contributed to an increase in surface temperature due to exposure to sunlight (Gardiner and Hassall 2009). Considering *Acrida cinerea*'s relatively large body size (especially in females), actively seeking sunlit locations may be beneficial for effectively warming up the body (Pielou 1948, Ahnesjö and Forsman 2006).

Grasshoppers from Oedipodinae are generally known to favor bare ground (Otte 1981, Craig et al. 1999, Chu 2002, Capinera et al. 2004). Therefore, it is not surprising that individuals of *Oedaleus infernalis* in our study were often observed on the bare soil exposed to sun. This preference might have provided thermal benefits, especially to females, which are relatively heavy (4–5 times heavier than *Atractomorpha lata* and male *Acrida cinerea)*. Warming up their heavy bodies is easier in hot locations on the ground. The body color of each grasshopper species seems to be well adapted to its own microhabitat. *Oedaleus infernalis* usually has a light brown body with dark brown stripes (Kim 2013), providing camouflage on typical ground coloration in the natural habitat. Conversely, the color of *Acrida cinerea* and *Atractomorpha lata* is usually green (Tanaka 2008, Pellissier et al. 2011), making it hard to recognize the individual grasshoppers against green plant parts. Additional camouflage is provided by the resting posture of *Atractomorpha lata*. With their hind legs tightly pressed against their body and pointy tips of head and wings visibly protruding, the individual grasshopper resembles a narrow green leaf. *Acrida cinerea* also have

Table 1. Number of individuals of the three grasshopper species observed on ground and plants. The category "Others" includes Fabaceae, Lamiaceae, Onagraceae, Polemoniaceae and Cannabaceae.

Substrate	Grasshopper			Total
	A. cinerea	*A. lata*	*O. infernalis*	
Ground	6	4	53	63
Asteraceae	18	116	7	141
Poaceae	51	22	28	101
Others				
Fabaceae	0	8	2	10
Lamiaceae	1	4	0	5
Onagraceae	0	3	1	4
Polemoniaceae	1	0	1	2
Cannabaceae	0	1	0	1
Total	77	158	92	327

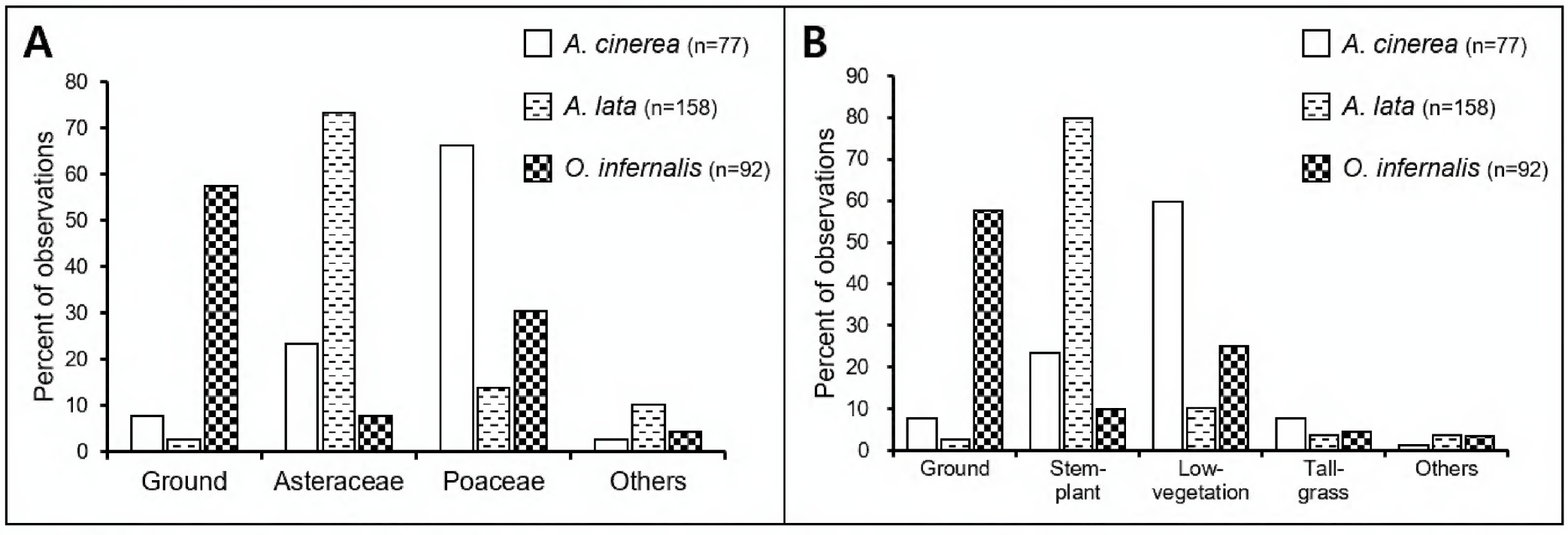

Fig. 1. The use of different types of substrates by the three grasshopper species. **A.** Substrates divided according to taxonomy; **B.** Substrates divided according to vegetation structure.

pointy head tips contributing to their camouflage while sitting on plant stems or grass leaves.

In summary, we documented microhabitat segregation among three common Asian grasshopper species and we hypothesized that food and microclimatic preferences, as well as phylogenetic history, might have contributed to the observed differences. These differences coincide with the differences between species in adaptations to camouflage their bodies in their respective microhabitats. Future experiments should determine if active preferences for specific habitats are responsible for the observed segregation, and if interspecific competition affects the segregation.

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